

Earth's Atmosphere

ES-4 The student will demonstrate an understanding of the dynamics of Earth's atmosphere.

Key Concepts for ES-4:

Atmosphere: structure (troposphere, stratosphere, mesosphere, thermosphere, exosphere), gas composition - ozone; thermal changes (tropopause, stratopause)

Convection cells: tropical, temperate, polar

Climate influences: latitude, topography, elevation, water proximity

Wind belts: trade winds, westerly winds, polar winds

Global climate change: ice ages, interglacial period, El Nino

Weather: air masses, high and low pressure systems, frontal boundaries

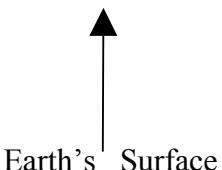
Storms: thunderstorms, hurricanes, tornadoes

ES-4.1 Summarize the thermal structures, the gaseous composition, and the location of the layers of Earth's atmosphere.

Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have encountered a study of moving “air” in 2nd and 4th grade and a study of gases in 3rd grade. Students were introduced to the concept of Earth's atmosphere and layers in 6th grade (6-4.1). This study included the identification of the layers; the gas composition within the layers, and differences in temperature within the layers. In Earth Science these concepts are revisited as students develop an understanding of the complexity of Earth's atmosphere.

It is essential for students to know that Earth's *atmosphere* is the layer of gases that surrounds the planet and makes conditions on Earth suitable for living things. It is a mixture of chemical elements and compounds differentiated by distinct differences in temperature with increasing altitude. This thermal structure differentiates the layers:

<p>Atmospheric Temperatures</p>	<p>Differences in temperature separate the layers.</p> <ul style="list-style-type: none"> • The cold regions of outer space extend from the <i>exosphere</i> • Even though the air is thin in the <i>thermosphere</i>, it is very hot; temperature increases as altitude increases • The <i>mesosphere</i> is the coldest layer; temperature decreases as altitude increases • The <i>stratosphere</i> is cold except in its upper region where ozone is located; high temperature zone, called the <i>stratopause</i>, marks the upper boundary • As altitude increases, temperature decreases in the <i>troposphere</i>; at the upper boundary, the <i>tropopause</i>, temperatures stop decreasing
<p>Atmospheric Layers</p> 	<p>Earth's atmosphere is divided into several different <i>atmospheric layers</i> extending from Earth's surface outward:</p> <ul style="list-style-type: none"> • the <i>exosphere</i> • the <i>thermosphere</i> • the <i>mesosphere</i> • the <i>stratosphere</i>, where the ozone layer is contained • the <i>troposphere</i>, where all weather occurs

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Atmospheric Gases	Nitrogen (N ₂) and Oxygen (O ₂)	<ul style="list-style-type: none"> the two most common gases; found throughout all the layers
	Ozone (O ₃)	<ul style="list-style-type: none"> a form of oxygen found in the stratosphere; in the upper atmosphere protects Earth's inhabitants from harmful ultraviolet rays of the Sun
	Water vapor (H ₂ O) and carbon dioxide (CO ₂)	<ul style="list-style-type: none"> most important compounds in the atmosphere; important gases for weather conditions; found in the troposphere
	Trace gases, for example argon	<ul style="list-style-type: none"> play an insignificant role

It is not essential for students to know the exact distance between each layer or the specific temperatures of the layers, or how the oxygen-carbon dioxide cycle and nitrogen cycle maintain stable amounts of those gases in the atmosphere. They do not need to compare the properties of pure air with air containing particulate matter and unnatural gases, polluted air, although this discussion would be interesting to increase the understanding of the effects of contaminants on pure air.

Assessment Guidelines:

The objective of this indicator is to *summarize* major points about the layers of Earth's atmosphere; therefore, the primary focus of assessment should be to generalize major points about the temperature differentiation in the layers, the gas composition of the layers, and the location of the layers in respect to Earth.

In addition to *summarize* appropriate assessments may require students to:

- *compare* one layer to another;
- *sequence* the layers from Earth outward; or
- *recall* gasses that are found in the atmosphere as to abundance and importance.

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ES-4.2 Summarize the changes in Earth's atmosphere over geologic time (including the importance of photosynthesizing organisms to the atmosphere).

Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concept in this indicator in any previous grade.

It is essential for students to know that Earth's early atmosphere was probably composed mainly of methane and ammonia. In the early forming of Earth, its surface was much more volcanically active than it is today.

- Earth's primitive atmosphere changed as erupting volcanoes emitted gasses such as water vapor, chlorine, carbon dioxide, hydrogen, and nitrogen.
- As the planet cooled, the water vapor condensed and absorbed most of the carbon dioxide; rains began to fall.
- Oxygen was probably formed from the breaking down of water molecules and also by photosynthesis of primitive cyanobacteria. Large mats and mounds of billions of cyanobacteria dominated the shallow oceans of Precambrian Earth. These organisms generated large amounts of oxygen, some of which also formed ozone, which, in turn, filtered out UV radiation so that other forms of life could survive on Earth's surface.
- As it appears, nearly all the oxygen that living things breathe today, and the oxygen that all animals have breathed in the geologic past, was released into the atmosphere primarily by photosynthesis.

It is not essential for students to know the details of photosynthesis or the processes by which volcanoes produce and spew gases during eruptions. An understanding of the evidence geologists have found in regards to early Earth's atmosphere is interesting but not essential.

Assessment Guidelines:

The objective of this indicator is to *summarize* the changes that have occurred to Earth's atmosphere over time; therefore, the primary focus of assessment should be to generalize major points about these changes and their causes, including the role of photosynthesizing organisms.

In addition to *summarize* appropriate assessments may require students to:

- *compare* the atmosphere of Earth today with Earth's earlier atmospheres; or
- *identify* causes of change to Earth's atmosphere.

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ES-4.3 Summarize the cause and effects of convection within Earth's atmosphere.

Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students were introduced to the concepts in this indicator in 6th grade (6-4.8). This study included explaining how convection affects weather patterns and climate. In Earth Science students will develop concept of the cause of convection within the atmosphere.

It is essential for students to know that *convection* is the transfer of heat energy in fluids, liquids or gases, by the movement of the heated particles.

- In convection, particles with higher energy move from one location to another carrying their energy with them.
- Particles with the higher energy move from warmer to cooler parts of the fluid.
- Because of Earth's spherical shape, the Sun's rays strike Earth more directly at the tropics than they do at the poles. At the poles, the same amount of solar radiation is spread over a larger area than at the equator. This unequal heating sets up the warmer-cooler regions necessary for global convection to take place in the atmosphere.

The air flowing from the equator completes three looping patterns of flow called *convection cells*. There are three atmospheric convection cells in the northern hemisphere and three in the southern hemisphere.

- The *tropical convection region* begins at the equator and extends to the about 30 degrees north or south latitude – warm air rises at the equator then cools enough to descend at about 30 degrees latitude from which air flows both north and south;
- The *temperate convection region* extends from there to about 60 degrees north or south latitude – descending air moves either back toward the equator or toward the poles where the air at about 60 degrees and warmed enough to create a low pressure area and again rise;
- The *polar convection region* extends from there to the poles, 90 degrees north or south latitude – air at the poles is descending cold air that moves toward the equator; at about 60 degrees it has warmed enough to begin rising.

Students should understand convection on a global scale in the atmosphere, which causes global winds, and therefore is the mover of weather systems in particular directions.

- Due to the spinning of Earth, the weather systems in these convection cells move in certain directions because the *global wind belts* are set up (ES-4.5).
- On a smaller scale, convection currents near bodies of water or near mountains can cause local winds known as *land and sea breezes* or *mountain and valley breezes*.

Because of the unequal heating of Earth, *climate* zones (tropical, temperate, and polar) also occur.

- Since temperature is a major factor in climate zones, students should relate climate to the convection regions at various latitudes, to temperature differences between the equator and the poles, and also to warm and cold surface ocean currents.

It is not essential for students to know the cause and effects of radiation (other than the angle of solar radiation) and conduction on the atmosphere. This indicator is not a complete study on the conditions related to climate. Climate is only related as an effect of global convection.

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Assessment Guidelines:

The objective of this indicator is to *summarize* the cause and effects of convection; therefore, the primary focus of assessment should be to generalize major points about how convection cells are caused and their effects within the atmosphere.

In addition to *summarize* assessments may require students to:

- *interpret* diagrams of convection cells;
- *explain* how the angle of solar radiation affects heating of Earth; or
- *compare* convection regions to the global wind belts.

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ES-4.4 Attribute global climate patterns to geographic influences (including latitude, topography, elevation, and proximity to water).

Taxonomy level: 4.3-B Analyze Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concepts in this indicator in any previous grade.

It is essential for students to know that climate is referred to as the average weather conditions of a region, the weather patterns that occur over many years. Scientists usually describe it in terms of the average monthly and yearly temperatures, or temperature range, and the average amount of precipitation.

Other factors also influence the temperature and precipitation of a climate region:

Latitude A major influence on the climate of a region is its distance from the equator – *latitude*. Latitude determines the amount of solar energy received by, and the prevailing wind belts of, the region. Climate zones based on latitude include tropical climates, middle-latitude climates, and polar climates.

Topography & Elevation The shape of the land, *topography*, also influences climate. Mountains influence the temperature and moisture content of air masses. Ascending air or descending air on mountain slopes causes differences in temperature and precipitation on the windward and leeward sides of the mountain. Since temperatures usually decrease with altitude, higher elevation climates are usually cooler than sea level climates.

Proximity to Water Water heats up and cools down more slowly than land. Thus, large bodies of water affect the climates of coastal areas. Many coastal regions are warmer in the winter and cooler in the summer than inland areas of similar latitude.

It is not essential for students to know the details for classification each particular climate region based on latitude or on the Koppen classification system based on distribution of vegetation.

Assessment Guidelines:

The objective of this indicator is to *attribute* global climate patterns to geographic influences, therefore, the primary focus of assessment should be to determine from presented material the geographic influence that relates to the particular climate pattern.

In addition to *attribute* appropriate assessments may require students to:

- *summarize* the major points about how each factor influences climate;
- *compare* the climate in a coastal region with one inland or a climate on the windward side of a mountain with one on the leeward side of the mountain; or
- *recall* the main factors used to identify a climate.

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ES-4.5 Explain the relationship between the rotation of Earth and the pattern of wind belts.

Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Students were introduced to global wind belts in 6th grade (6-4.9) as they studied the effects that global winds had on weather and climate conditions. The Coriolis effect has not been introduced in any prior grades.

It is essential for students to know that the circulation of the atmosphere is affected by the rotation of Earth on its axis. The rotation causes the surface winds in the Northern Hemisphere to be deflected to the right and those in the Southern Hemisphere to be deflected to the left. This motion is called the *Coriolis effect*. The Coriolis effect deflects winds that would otherwise blow directly from a high-pressure area toward a lower-pressure area from that path.

Because convection cells are in place in the atmosphere and Earth is spinning on its axis, *global winds* are found in each convection region. Students need to understand the *global wind belt* regions, the prevailing direction of the wind, and how air movement in these large regions affects weather patterns.

<i>Trade winds:</i>	<ul style="list-style-type: none">The <i>trade winds</i> blow from east to west in the tropical region moving warm tropical air in that climate zone. Like all winds they are named according to the direction from which they flow, the northeast trade winds or the southeast trade winds.
<i>Westerly winds:</i>	<ul style="list-style-type: none">The prevailing <i>westerly winds</i> blow from west to east in the temperate region. The temperate zone temperatures are affected most by the changing seasons, but since the westerly wind belt is in that region, the weather systems during any season move generally from west to east. Since the United States is in the westerly wind belt, the weather systems move across this country from west to east. (Tropical weather systems, for example, hurricanes, are moved in the prevailing easterly direction of the trade winds. If they enter the westerly wind belt, they are often turned, and move in the direction of that prevailing system.)
<i>Polar winds:</i>	<ul style="list-style-type: none">The <i>polar winds</i> blow northeast to west in the polar region, often called the polar easterlies, moving cold polar air in that climate zone from the poles toward the west. Where the polar easterlies meet warm air from the westerlies, a stormy region known as a <i>polar front</i> forms.

It is not essential for students to know the details of shifts in wind belts due to changes in seasons or the cause and effects of the jet streams.

Assessment Guidelines:

The objective of this indicator is to *explain* how the rotation of Earth is related to global wind belt patterns; therefore, the primary focus of assessment should be to construct cause and effect models of global winds responding to the Coriolis effect due to the rotation of Earth.

In addition to *explain* appropriate assessments may require students to:

- *compare* the wind belt regions as to wind direction and influence on weather patterns;
- *recall* the effect on surface winds of the Coriolis effect; or
- *identify* global wind belts based on descriptions.

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ES-4.6 Summarize the possible causes of and evidence for past and present global climate changes.

Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concepts in this indicator in any previous grade.

It is essential for students to know that some years Earth may be warmer, cooler, wetter, or drier than others, but on the average during a person's lifetime, climate does not change significantly. However, in Earth history evidence shows that Earth's climate has changed and is in a constant state of change. Major climate changes take long time periods.

Ice ages A long period of climatic cooling during which continental ice sheets, glaciers, cover large areas of Earth's surface is known as an ice age, or *glacial period*. Scientists have discovered several major glacial periods during Earth history. Features such as U-shaped valleys and moraine deposits are evidence of how far ice sheets advanced during an ice age.

Interglacial Period Times of warmer temperatures between the colder glacial periods are known as interglacial periods. Earth is currently experiencing such an interval.

Cause: One theory states that possibly a small change in Earth's orbit or in the tilt of Earth's axis occurs – basically a change in the amount of solar energy reaching Earth's surface. Another theory proposes that ice ages were caused by tectonic plate motion changing the position of the continents; others propose that volcanic dust blocked the Sun's rays.

Evidence: Evidence gathered from tree rings, ice-core samples, fossils, and radiocarbon sample provide evidence of past climatic changes. Evidence has also come from the ocean floor in the shells of dead marine animals.

Present short-term climate changes also occur.

El Nino El Nino is a warm ocean current that occasionally develops off the western coast of South America forming around Christmas time about every three to ten years and lasting about a year. It can cause climate changes world-wide, especially in the tropics by weakening the trade winds in that area of the Pacific. This allows warm water to flow eastward instead of its usual westerly direction, changing the cool, dry region to a warmer, wetter one. It also changes the subtropical jet stream causing unusual weather around the world.

It is not essential for students to know the details of glaciers and ice movement.

Assessment Guidelines:

The objective of this indicator is to *summarize* the cause and evidence for past and present climate changes; therefore, the primary focus of assessment should be to generalize major points about these changes.

In addition to *summarize* appropriate assessments may require students to:

- *recall* conditions on Earth during an ice age; or
- *exemplify* evidence for climate change such as ice ages.

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ES-4.7 Summarize the evidence for the likely impact of human activities on the atmosphere (including ozone holes, greenhouse gases, acid rain, and photochemical smog).

Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concepts in this indicator in any previous grade.

It is essential for students to know that human activities have an impact on Earth's atmosphere. Global atmospheric effects include ozone depletion, global warming, acid precipitation, and air pollution, such as photochemical smog, ozone, and particulate matter.

Ozone depletion

Ozone depletion results from human activity through the use of chlorofluorocarbons (CFCs).

- CFCs are stable and harmless near Earth's surface but when they move into the upper atmosphere, they destroy ozone molecules that protect Earth from harmful ultraviolet radiation.
- Since the mid-1980s studies of the atmosphere have detected a thinning of Earth's protective ozone layer, most dramatically over Antarctica, called the "ozone hole".
- Because all CFCs released into the atmosphere are from man-made products, ozone depletion is entirely the result of human activity.

Global warming

Global warming is natural for Earth's atmosphere to trap heat in the troposphere; this is known as the *greenhouse effect*.

- Global warming is the increase in Earth's average surface temperature.
- This is partly caused by human activities especially the burning of fossil fuels that significantly increases amounts of carbon dioxide, a main *greenhouse gas*, released into the atmosphere.
- Carbon dioxide absorbs heat very readily. Increases in amount of carbon dioxide will intensify the greenhouse effect and may cause Earth to become warmer.
- The presence of other gases such as methane and CFCs also has an effect on the warming of the atmosphere. Much of the methane and all of the CFCs were put into the atmosphere by human activity.
- Increases in global temperatures can have dramatic effects, such as changes in agricultural belts, glacier-ice cap melting resulting in rise in sea level, and difficulty of certain plants and animals to adapt resulting in extinction.

Acid precipitation

Acid precipitation, or *acid rain*, is defined as precipitation with a pH of less than 5.0.

- Natural precipitation has a pH of about 5.0 to 5.6, which is slightly acidic.
- Sulfuric and nitric acid results when precipitation combines with sulfur dioxide and nitrogen oxides in the atmosphere.
 - Sulfur dioxide is produced primarily by burning fossil fuels such as coal that contains sulfur.
 - Nitrogen dioxide is produced by the high temperatures and pressures that exist inside internal combustion engines such as those in automobiles.
- These acids can be carried by winds long distances, thereby affecting areas far from their source.
- When acid precipitation makes its way into water bodies, it causes damage to the aquatic ecosystems and vegetation. It can affect plants and soil. Acid rain also damages stone buildings, statues, and even metal structures accelerating the processes of weathering and corrosion.

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Air pollution

The air near Earth's surface can become polluted several ways.

- *Photochemical smog*, a yellow-brown haze in the air, is caused by the action of solar radiation on an atmosphere polluted with hydrocarbons and nitrogen oxides, mostly from automobile exhaust systems. The air becomes harmful to breathe.
- A major chemical in smog is *ozone* – in the upper atmosphere it is beneficial, but near the surface it is a pollutant. Ozone irritates the eyes, nose, and lungs of humans and is also harmful to plants.
- Air pollution also occurs when *particulate matter*, such as carbon ash, dust, pollen, or asbestos fibers accumulate in the atmosphere. These particles are breathed in and lodge in the nose and lungs disrupting normal functions.

It is not essential for students to know the chemistry behind the formation of these types of pollution. They do not need to complete acid/base/neutralization reactions; although taking pH readings from water or soil samples might help in the summary. Even though this human impact leads to the need for reducing air pollution, that would be an interesting discussion but not essential to this indicator.

Assessment Guidelines:

The objective of this indicator is to *summarize* the evidence for human impact on the atmosphere; therefore, the primary focus of assessment should be to generalize major points about the ways that human activity has resulted in changes in Earth's atmosphere.

In addition to *summarize* appropriate assessments may require students to:

- *compare* these various types of atmospheric effects;
- *compare* the types and sources of air pollution;
- *identify* the causes of these impacts on the atmosphere; or
- *recall* the effects that these impacts can have on human beings and the environment.

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ES-4.8 Predict weather conditions and storms (including thunderstorms, hurricanes, and tornadoes) on the basis of the relationship among the movement of air masses, high and low pressure systems, and frontal boundaries.

Taxonomy level: 2.5-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 4th grade summarized the conditions and effects of severe weather including thunderstorms, hurricanes, and tornadoes. In 6th grade students summarized the relationship of the movement of air masses, high and low pressure systems, and frontal boundaries to storms and other weather conditions. In Earth Science this foundation will be deepened as the complexity of air movement of and within weather systems are studied so that predictions can be made.

It is essential for students to know that *weather* is the current, day-to-day, conditions of the atmosphere. Air masses, high and low pressure systems, and frontal boundaries are the major causes of weather variations and storms. Many meteorological processes involve atmospheric movement, such as convection, on different scales. Predicting weather conditions and storms comes from knowing that they are part of and the result of relationships among the following factors in the atmosphere.

Air masses Students need to know how an air mass forms, the types of air masses that usually affect North America, and the source regions for these air masses. They should understand that as air masses move their characteristics modify according to the surface(s) over which they travel.

High pressure system Students need to know that sinking air is associated with high pressure systems, also called *anticyclones*. With the Coriolis effect, sinking air circulates downward and to the right in the northern hemisphere spreading away from the center when it reaches Earth's surface. High pressure systems rotate clockwise. High pressure systems are usually associated with fair weather and generally pleasant conditions.

Low pressure system Students need to know that in surface low pressure systems, also called *cyclones*, air rises. Rising air must be replaced, so the flow of air is inward toward the center and then upward. A low pressure system in the northern hemisphere moves in a counterclockwise direction. Low pressure systems are usually associated with clouds and precipitation.

Fronts Students need to know how air masses influence the formation of the four main types of fronts: *cold* front, *warm* front, *occluded* front, and *stationary* front. They need to know the direction of airflow within the frontal region and what factor(s) influences the direction of frontal movement. They need to know the characteristic cloud formations and weather patterns that result from each frontal boundary.

It is also essential for student to know about the factors that influence weather conditions in order to gain an understanding of storms.

- The major storms – thunderstorm, hurricanes, and tornadoes, are associated with low pressure cyclonic movement of air and/or frontal boundaries.
- Students need to know the conditions under which these storms form, how they are related to the factors that influence weather conditions (air masses, pressure systems, and fronts), and also factors concerning their duration and severity.
- Plotting the course of a hurricane and predicting its possible path based on atmospheric conditions is also essential in the study of this storm.

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It is essential for students to use weather map data that includes air masses, pressure systems and isobar lines, and fronts (as well as station model data) to predict weather conditions in regions across the United States.

It is not essential for students to actually collect weather data using weather instruments (4th and 5th grade). The reading of radar images or infrared satellite images though interesting is not essential.

Assessment Guidelines:

The objective of this indicator is to *predict* weather conditions and storms; therefore, the primary focus of assessment should be to make logical predictions from presented information, including air masses, high and low pressure systems, and frontal boundaries.

In addition to *predict* appropriate assessments may require students to:

- *summarize* the formation and severity of different storms;
- *compare* high and low pressure systems;
- *compare* the formation and weather conditions of the different fronts;
- *interpret* diagrams or illustrations of air masses, pressure systems, and fronts; or
- *predict* weather conditions from information on a weather map.